STEEL | INDUSTRIAL APPLICATION | PENSTOCK | EPOXY

Quite a Pair: Robots Used to Reline Penstocks

BY **LISA SCIORTINO**
PHOTOS COURTESY OF **HARTMAN WALSH INDUSTRIAL SERVICES**

The breathtaking-yet-rugged terrain surrounding the Cheakamus Generating Station in British Columbia, Canada, presented plenty of challenges for the crew of St. Louis, Mo.-based Hartman Walsh Industrial Services.

The 75-year-old company, which has a reputation in North America as an industry leader in penstock rehabilitation, has worked over the past five-plus years recoating the interior and exterior surfaces of the facility's aged penstocks for Canadian electric utility provider BC Hydro.

The job began in 2019 and was scheduled to wrap up earlier this fall. During that time, the crew encountered and successfully overcame various obstacles, including the penstocks' steep, remote location; scheduling work during water system service outages; and work stoppages due to excessive rainfall and the COVID-19 pandemic.

"This job was an animal beyond any job I've ever been on," said Jess Chism, project manager with Hartman Walsh. "It's really a feather in the cap of anybody who's been involved just to say that we got it done."

Nestled amid the soaring mountains and towering trees of the Squamish Valley, about halfway between the cities of Vancouver and Whistler, the hydroelectric facility has operated since 1957.

For nearly seven decades, water has been diverted from the adjacent Cheakamus River, a tributary of the Squamish River, at Daisy Lake dam and reservoir. After being funneled through a canal below the scenic Sea to Sky highway, it enters an approximately 6.8-mile-long (~11-km) tunnel in Cloudburst Mountain.

The water is then carried by the penstock's pair of 2,000-foot (609.6-m)-long, 8.75-foot (2.667-m)-diameter steel

The Hartman Walsh Industrial Services crew began work on the Cheakamus penstocks in 2019 by installing multiple manways along the pipes to gain access to their corroded interiors.

Scaffolding was constructed around the BC Hydro penstocks prior to exterior surface preparation, which included abrasive blasting operations.

pipes — dubbed Unit 1 and 2 — to the Cheakamus Generating Station's twin turbines. There, it generates electricity for residents of British Columbia before being discharged into the Squamish River.

After so many years of use, the interior and exterior coatings on the massive pipes — which are situated on a mountainside at an approximate 40-degree incline — had failed.

"These things had just been sitting for 60 to 70 years, basically corroding away," Chism said.

Gaining Access

Hartman Walsh was selected for the project through a technical request for proposal. The company was tasked with removing corrosion and existing coatings through waterjetting and abrasive blasting. They were also assigned to reline 100,000 square feet (9,290.3 m^2) of interior surface and recoat 90,000 square feet (8,361.3 m^2) of exterior surface to prevent additional corrosion and extend the penstocks' service life.

Twenty-five Hartman Walsh crew members from various parts of Canada worked two 10-hour shifts six days per week for the duration of the job, which also included blasting and recoating a 400-foot (121.9-m) section of a steel-lined rock tunnel at the Cheakamus Generating Station.

"You've got a rock tunnel that goes through a mountain, probably 5 kilometers [or] roughly 3 miles, until you hit the penstock. It daylights out of the mountain and converts to steel at that point," Chism explained.

Prior to the start of work, Hartman Walsh consulted with BC Hydro to determine where access roads to the penstocks should be built by subcontractors through the surrounding wilderness. "These facilities were built in the '50s, so they didn't have good access into these places," Chism said.

Once the penstocks were accessible, Hartman Walsh began by installing four manways approximately 400–800 feet (122–244 m) apart along the pipes (depending on where roads had been built) to create new access points. "These penstocks are 2,000 feet [609.6 m] long," Chism said. "We needed to get [access] into the middle of them."

Ready for Robotics

Decades of funneling frigid glacial runoff had severely corroded the penstocks' interiors. "The insides were in really rough shape," Chism said. "A lot of the penstocks in the [United] States that we see are [coated with] hot-applied coal tar enamel.... These had 5 to 10 mils [127 to 254 microns] of lead-based paint on them initially, and it was almost 100-percent gone."

Hartman Walsh brought in three proprietary, multi-million-dollar, robotic blasting and coating application machines that the company developed for use specifically on this project. "We're the only company in the United States that has [this] technology," Chism said.

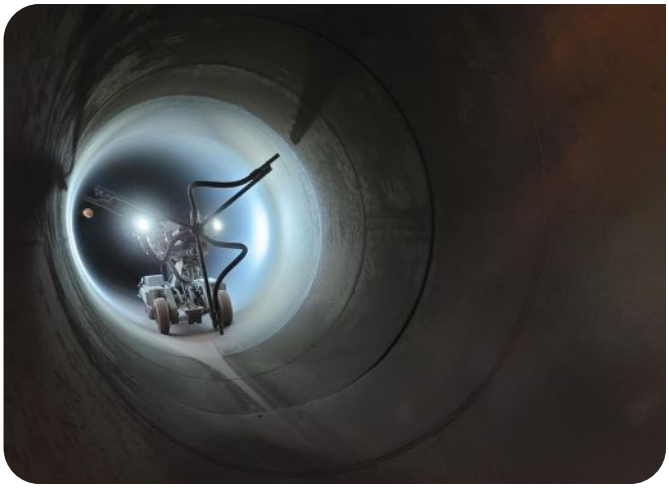
Hydraulic cranes, from manufacturer Hiab, were used to move the robots into and around the jobsite. Weighing approximately 2,500 pounds (~1,134 kg) each, the versatile, unmanned robots are the first of their kind, Chism said.

The machines are affixed to a chassis and feature additional equipment — including cameras and sensors — that a crew member operates from outside the penstocks. From an on-site, shipping container-style office serving as a control center, "the operator sits and is able to view the [attached] cameras on TV screen and the control panel to tell [the machine] to turn left, turn right, start blasting, stop blasting," Chism explained.

Meanwhile, other crew members work to "help tie hoses and help tie cables and attach them to winches... that are pulling the robots up and down [the pipe].... At the same time, you still [are working in] a confined space. A guy may pop in and out of there [to] make sure stuff looks right."

The robotic equipment can be modified to work in

Hartman Walsh developed three multi-million-dollar, robotic blasting and coating application machines specifically for the Cheakamus penstocks' project.



Crew members occasionally worked within the confined spaces of the penstocks' interiors, attaching winches to the robotic blasting and coating machines.

confined spaces ranging from 5 to 13 feet (1.5 to 4.0 m). They also feature swappable components that allow them to switch from performing waterjetting operations to abrasive blasting and, finally, to applying coatings.

"We try to make it so that they are capable of multiple operations. It's just less parts that we have to bring in and out because they're super heavy.... and we're trying to get them through 20- or 24-inch [~51-cm or ~61-cm] manways," Chism said. "They're kind of like modular LEGO pieces that we try to make big enough that we don't have to take as many of them apart, but small enough that we can still get them through the spaces."

Given the steep incline, limited access, and confined spaces of the Cheakamus penstocks, Chism said that developing and using robotic equipment was the best — and safest — option for the job.

"If it's reasonable to eliminate the risk by removing people and doing a lot of this [work] more assisted, then that's what we have to do," he said.

Hartman Walsh also followed Safety by Design principles to proactively mitigate potential jobsite hazards and related risks.

"We engineer out the vast majority of the hazards, wherever we can," Chism said. "We didn't use any solvents in [the penstocks], not even to clean with. We didn't use any kind of solvent [-based] paints. It was all 100-percent solids materials. But you still want to reduce the amount of man hours that you're spending in there."

Safety was top of mind for the Hartman Walsh crew throughout the job. The rescue- and rope access-trained team used personal protective equipment, including 3M DBI-SALA harnesses and lanyards, and participated in rescue drills. Meanwhile, scaffolding and containment systems helped to also protect them from injury, as well as the surrounding pristine wilderness.

JOB AT **A GLANCE**

PROJECT:
Recoat two 2,000-foot-long penstocks at a hydroelectric facility

COATINGS CONTRACTOR:
Hartman Walsh Industrial Services
St. Louis, MO
(314) 863-1800
FB: Hartman Walsh Industrial Services
https://hartmanwalsh.com

SIZE OF CONTRACTOR:
~200 employees

SIZE OF CREW:
25 crew members

PRIME CLIENT:
BC Hydro
Vancouver, British Columbia, Canada
(800) 224-9376
FB: BC Hydro
www.bchydro.com

SUBSTRATE:
Steel

CONDITION OF SUBSTRATE:
Heavy corrosion on interior and exterior

SIZE OF JOB:
190,000 sq. ft. (100,000 interior; 90,000 exterior)

DURATION:
5 years, on and off

UNUSUAL FACTORS/CHALLENGES:
- Manways were installed to create access points on the penstocks.
- The crew faced several unplanned work stoppages, including when unmanned robotic equipment required repairs.

MATERIALS/PROCESSES:
- Robotic machines performed ultra-high pressure waterjetting; abrasive blasting followed to achieve SSPC-SP 10 "Near White Metal Blast Cleaning" standard on interior surfaces
- Applied single coat of Duromar HPL-2510 at approximately 40–60 mils with robotic equipment
- Following surface prep to achieve SSPC-SP 6 "Commercial Blast Cleaning" standard, used MQ Power generators, Climate by Design dehumidifiers, and Smart Family air conditioners to regulate conditions within containment system during exterior coating operations
- Applied single coats of Carboline's Carbozinc 859 primer, Carboguard 635 HAR epoxy, and Carbothane 134 HG to exterior surfaces at approximately 10–20 mils

SAFETY CONSIDERATIONS:
- Standard PPE gear included 3M DBI-SALA fall protection harnesses and lanyards
- Crew members followed Safety by Design principles, 100-page safety and environmental management plans, and participated in rescue drills
- CRSP/Certified Industrial Hygienist was on site full time

For an added layer of oversight, a Canadian Registered Safety Professional (CRSP) and Certified Industrial Hygienist were on-site full time to help ensure the job's approximately 100-page safety and environmental management plans were followed.

VENDOR **TEAM**

3M
Safety equipment manufacturer
St. Paul, MN
(800) 364-3577
X: 3M
www.3m.com

ARS Recycling Systems
Equipment manufacturer
Lowellville, OH
(330) 536-8210
X: ARSRecycling
www.arsrecycling.com

Carboline
Coatings manufacturer
St. Louis, MO
(314) 644-1000
X: carboline
www.carboline.com

Clemco Industries Corp.
Equipment manufacturer
Washington, MO
(636) 239-0300
LI: clemco-industries-corp
www.clemcoindustries.com

Climate by Design International
Equipment manufacturer
Owatonna, MN
(507) 451-2198
FB: ClimateByDesignInternational
www.cdihvac.com

Doosan Portable Power
Equipment manufacturer
Statesville, NC
(704) 883-3500
X: DoosanPortable
www.doosanportablepower.com

Duromar
Coatings manufacturer
Pembroke, MA
(781) 826-2525
https://duromar.com

GMA Americas
Material manufacturer
The Woodlands, TX
(832) 240-7767
X: GMA_Garnet
www.gmagarnet.com

Graco Inc.
Equipment manufacturer
Minneapolis, MN
(800) 275-5574
X: GracoInc
www.graco.com

Hiab USA
Equipment manufacturer
Perrysburg, OH
(419) 482-6000
FB: Hiabusa
www.hiab.com

Jetstream of Houston
Equipment manufacturer and supplier
Houston, TX
(800) 231-8192
X: waterblast
www.waterblast.com

Northstar Access
Equipment contractor and supplier
Port Coquitlam, British Columbia, Canada
(604) 291-7245
FB: NorthstarAccess
https://scaffolding.ca

Smart Family of Cooling Products
Equipment manufacturer
Houston, TX
(281) 540-2805
X: SmartCooling
www.smartcoolingproducts.com

A Learning Year

The Hartman Walsh crew worked on the penstocks during the first BC Hydro-scheduled, three-month water-service outage in late 2019.

After installing the manways, interior surface preparation got underway on Unit 1 with ultra-high pressure waterjetting, performed by Hartman Walsh's robotic equipment that was equipped with Jetstream pumps, to achieve the Society for Protective Coatings (SSPC)-SP1 "Solvent Cleaning" standard. Waterjetting also worked to reduce risks to the crew that existed due to the heavy scale and mineral deposits and some residual lead paint inside the penstocks.

Abrasive blasting operations followed, also performed by the robotic equipment, to remove the remaining lead paint. Using Clemco 8-ton/160-cubic-foot (~7. 3-t/4.5-m^3) blast pots powered by 1,600 CFM (~281.5 m^3/h) Doosan air compressors, GMA Garnet abrasive blast media, and ARS Recycling Systems dust collectors, the crew achieved the SSPC-SP 10 "Near White Metal Blast Cleaning" standard.

The team was initially confident that work could be completed on Unit 1 during the first service outage. However, the 40-degree slope of the penstocks proved more difficult than anticipated.

"We have [worked on] a lot of large-diameter piping, but [the slope] was much flatter. You could pretty much walk [in the pipe] if you had to," Chism said. "In this situation, the productivity is much lower working on a slope like this."

To make matters worse, some of Hartman Walsh's robotic equipment sustained damages during abrasive blasting operations inside Unit 1, and it required repairs.

"We didn't even know there was a problem until [the cameras] went dark," Chism said. "So then, we went down there on cables and ropes to figure out what happened."

The Hartman Walsh crew worked within a shrink wrap containment system while abrasive blasting and coating the Cheakamus penstocks' exterior surfaces.

Heavy regional rains during late 2019 necessitated an unexpected return to service for the penstocks, which forced the crew to cease its interior work. Pandemic shutdowns in 2020 caused additional delays.

"We didn't even get to [applying] the coatings because we just ran out of time," Chism said. He described the first year of the project as "basically a learning year. We worked through the outage and figured out what problems we had with the equipment — first-time use, what breaks, what works, what doesn't."

With the robotic equipment repaired, work resumed on Unit 1 in 2021. The crew completed interior waterjetting and abrasive blasting before applying a single coat of Duromar HPL-2510 at approximately 40–60 mils (1,016–1,524 microns). The 100-percent solids, plural-component epoxy features a modified amido amine hardener and is ideal for use on circulating water pipe, process water tanks, and sewage treatment systems.

Chism said Hartman Walsh uses Duromar products almost exclusively on the three to four penstock jobs it does annually. "They fit our application and logistical challenges on these projects pretty well."

The crew completed the interior coatings on Unit 1 later that year and, in 2022, began blasting and recoating the steel-lined rock tunnel.

From the Bottom Up

In 2023, interior waterjetting, abrasive blasting, and coating operations began on Unit 2 and were completed during a springtime water service outage.

With exterior-surface abrasive blasting operations also set to begin that year, Vancouver-based subcontractor Northstar Access arrived on site and installed a scaffolding system. Another Vancouver subcontractor, Elements, encased the scaffolding in a 12-mil (304.8-micron) shrink wrap containment system.

In 2024, exterior surface prep began with abrasive blasting using the same GMA Garnet abrasive blast media to achieve the SSPC-SP 6 "Commercial Blast Cleaning" standard. Because the job no longer involved working in confined spaces, the robotic equipment was not needed.

The penstocks were operational while abrasive blasting and coating was performed on 100-foot (30.5-m) exterior sections of the pipes. "We worked our way from the bottom up because there's a little bit less slope at the bottom," Chism said.

The combination of icy water flowing through the penstock interiors and sunlight warming the pipes' exterior surfaces could have resulted in extreme temperature differentials and caused condensation to form on the steel substrate, which would have disrupted the crew's work.

To avoid this situation, Hartman Walsh fired up four 1,000-kilowatt MQ Power generators to power 5,000 CFM (8,495.05 m^3/h) Climate by Design dehumidifiers and 10,000 CFM (16,990.1 m^3/h) Smart Family-brand air conditioners. The combination successfully removed excess moisture from the air and helped maintain optimal conditions within the shrink-wrapped containment area.

The pestocks' exterior surfaces received one coat each of Carboline's Carbozinc 859 zinc epoxy primer, Carboguard635 HAR epoxy, and Carbothane 134 HG at approximately 10–20 mils.

"This is the only job I've ever had to do that on," Chism said. "You really had to drop the dewpoints… so you can keep those penstocks from sweating."

Once abrasive blasting operations were completed, Graco airless spray pumps were used to apply on the penstocks' exterior surfaces a coat of Carboline's Carbozinc 859, a fast-curing, low-volatile organic compounds, organic zinc epoxy primer.

That was followed by a coat of Carboline's Carboguard 635 HAR, an all-purpose, abrasion-resistant epoxy, and a final finishing coat of high-gloss, corrosion-resistant Carbothane 134 HG. Each coating was applied at approximately 10–20 mils (254–508 microns).

"On this project in particular, when you have very cold steel [and are] running glacial water through [the pipes], we needed fast cure times," Chism said. "Carboline had the most advantageous system in our initial review of what worked logistically for our application."

Lessons Learned

Due to the size, scope, and challenges it presented, the Cheakamus penstocks job is one the Hartman Walsh team will never forget.

"We have a lot of pride for having completed it," Chism said. "It's one of those jobs that you could show to anybody and they'd say, 'Wow, that's a crazy project.' … It was a lot of lessons learned that have helped us execute other projects (and) develop technology that hadn't existed."

"It was a good job, and we gained a lot of industry respect from it." ***CP***